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COMPRESSIVE STRENGTH OF CORRUGATED-SHEET-STIFFENED PANELS FOR CONSOLIDATED XB-36 AIRPLANE

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MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

COMPRESSIVE STRENGTH OF CORRUGATED-SHEET-STIFFENED PANELS FOR CONSOLIDATED XB-36 AIRPLANE

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Compression tests were made of 63 panels stiffened with corrugated sheet. The specimens were constructed from artificially aged alclad 24S-T aluminum alloy with minimum guaranteed yield strengths of 57 and 48 kips per square inch for the flat- and corrugated-sheet materials, respectively.

Results of the tests are presented in charts which show the average stresses at the maximum load and at buckling of the sheet.

INTRODUCTION

To provide information on the compressive strength of stiffened panels, the proportions of which vary over an extensive range, tests were performed at tho request of the Army Air Forces on panel specimens with corrugated-sheet stiffening. The specimens were made by the Consolidated Vultee Aircraft Corporation.

The thicknesses of the flat and corrugated sheets and the specimen length were varied systematically for two sizes of corrugation to show the effects of changes In these dimensions on the strength of the panels.

TEST SPECIMENS

Cross sections of the two types of specimen are shown in figures 1 and 2. The material of the specimens was artificially aged alclad 24S-T aluminum alloy with the grain of both the flat and the corrugated sheet parallel to the corrugations. Twenty-seven of the panels were of the cross section shown in figure 1, and 36 were of the cross section shown in figure 2.

The cross-sectional area was determined from the density of the material and the weight and length of each specimen, with proper allowance for the weight of the rivet heads.

Proportions of the test specimens are designated by the symbols shown in figures 1 and 2, and the nominal dimensions, furnished by the manufacturer, are given in the charts that present the test results. In the preparation of the test data actual values of the dimensions, obtained by measurement of the specimens, were used.

Method of Testing

The specimens were tested in the 1,200,000-pound-capacity testing machine in the National Advisory Committee for Aeronautics structures-research laboratory. Figure 3 shows one of the specimens under test. The ends of each specimen were carefully ground flat, parallel to each other, and square with the longitudinal axis of the specimen. The alinement of the specimens in the testing machine so as to retain the flatness and parallelism of the ends was accomplished by means of the guide bars shown in figure 3. These guide bars were backed away from the specimen before the maximum load was reached.

Strains on the flat and corrugated sheets were measured by wire-resistance-type strain gages. The strain gages on the flat sheet were located in pairs attached to opposite sides of the sheet. Figure 4 shows the location of the gages on the stiffener side of the flat sheet. These gages were attached to the flat sheet before the riveting operation. The lead wires from the strain gages were brought out through holes in a hardened bearing block in order to avoid drilling holes in any part of the specimen. The over-all shortening of each specimen was measured with dial indicators.

Test Results

The average stress at maximum load was determined for each panel. This stress was adjusted to apply to a panel that did not include the area of flat and corrugated sheet beyond the outer rows of rivets. It was adjusted also to minimum guaranteed properties of the materials. The procedures by which these adjustments were performed are described in the appendix.

The strengths of the panels as shown in figures 5 and 6 were obtained in flat-end tests in which the average coefficient of end fixity was assumed to be 3.75. (See appendix.) As the aircraft designer i more frequently interested in the strength of panel considered as columns with end-fixity coefficients of $c = 1$ or $c = 1.5$, the actual lengths of the specimens have been reduced to equivalent lengths corresponding to the latter two values of the end-fixity coefficient. The abscissa scales on the charts therefore show the lengths of corrugated-sheet panels with end-fixity coefficients of $c = 1$ and $c = 1.5$ and with strengths equal to those of the test specimens.

The average stress at which buckling of the sheet occurred was determined for the specimens by the method described in the appendix. Buckling stresses for specimens with the same cross section but with different lengths were averaged, and this averaged stress is indicated in figures 5 and 6 by a short horizontal line.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 28, 1944.

APPENDIX

The manner in which the test data should be presented was decided in conference with Dr. H. L. Langhaar, of the Consolidated Vultee Aircraft Corporation. The procedure is similar to that of reference 1. The test data for each specimen included strain measurements on the flat and the corrugated sheet and over-all shortening of the panel at a number of loads varying from the initial load to a load near maximum.

The symbols used in the equations and figures for preparation and presentation of the test results are as follows:

a distance from outer row of rivets to edge of sheet, in.

b_c depth of corrugation, in.

b_r distance between adjacent rivet rows, in.

c fixity coefficient in the Euler column formula

t_c thickness of corrugated sheet, in.

t_s thickness of flat sheet, in.

A cross-sectional area of specimen, sq in.

A_c cross-sectional area of corrugated sheet, sq in.

A_s cross-sectional area of flat sheet, sq in.

F_{YP} weighted compressive yield strength for a panel in which the flat and corrugated sheets do not extend beyond the outer rivet rows, ksi

$(F_{YP})_c$ compressive yield strength for corrugated sheet, ksi

$(F_{YP})_s$ compressive yield strength for flat sheet, ksi

L specimen length, in.

P maximum load on panel, kips

σ' adjusted average stress at maximum load for a panel in which the flat and corrugated sheets do not extend beyond the outer rivet rows, ksi

σ_c stress in corrugated sheet at maximum load, ksi

σ_s stress in flat sheet at maximum load, ksi

The essential steps taken in preparing the test data for presentation are as follows:

1. The load on the specimen was plotted against the shortening per inch of specimen length, and the strain at maximum load was obtained by extrapolation of the curve drawn in this plot. The strain was converted to stress in the corrugated sheet σ_c by use of the stress-strain curve for the corrugated-sheet material.

2. At maximum load, the longitudinal strain in the flat sheet near the rivet rows was assumed to be the same as the longitudinal strain in the corrugated sheet. This strain in the flat sheet was converted to stress σ_s by use of the stress-strain curve for the flat-sheet material.

3. The average stress at maximum load for each specimen was adjusted to apply to a panel in which the flat and corrugated sheets do not extend beyond the outer rivet rows. This adjusted average stress was obtained by the equation

$$\sigma' = \frac{P - 2a(t_s\sigma_s + t_c\sigma_c)}{A - 2a(t_s + t_c)}$$

4. The adjusted average stresses of step 3 were also adjusted for minimum guaranteed material properties by the method described in reference 2. Because the sheet and stiffening materials possessed different properties, it was necessary to determine a weighted yield strength for a panel. The weighted compression yield strength used for the panels of this investigation is given by

$$F_{YP} = \frac{(F_{YP})_c(A_c - 2at_c) + (F_{YP})_s(A_s - 2at_s)}{(A_c - 2at_c) + (A_s - 2at_s)}$$

The weighted guaranteed compression yield stress for a panel is obtained from the preceding equation when the minimum guaranteed yield strengths of 48 and 57 ksi are substituted for $(F_{YP})_c$ and $(F_{YP})_s$, respectively. These minimum guaranteed yield strengths were supplied by the Consolidated Vultee Aircraft Corporation.

The average stress at maximum load that is obtained from steps 3 and 4 is the average stress, adjusted for standard material properties, for a panel in which the flat and corrugated sheets do not extend beyond the outer rivet rows.

5. Tests in the 1,200,000-pound-capacity testing machine in the NACA structures-research laboratory indicate that an average end-fixity coefficient of about 3.75 is obtained in flat-end tests of panels similar to the panels of this investigation. This value, then, was assumed to apply to all panels with corrugated-sheet stiffening.

The pin-end length of a panel that is equivalent to a panel with end-fixity coefficient of 3.75 was determined by multiplying the actual length of the test specimen by

$$\sqrt{\frac{1}{3.75}}$$

For these values of pin-end length, the adjusted average stress at maximum load was plotted using the upper abscissa scale presented in the figures. The lower abscissa scale for $c = 1.5$ was obtained by multiplying values of length on the upper scale by

$$\sqrt{\frac{1.5}{1}}$$

6. Buckling of the flat sheet was determined from the longitudinal strain measurements made on the panel. Each width of flat sheet between rivet rows was considered to be a long flat plate with the loaded edges at the ends of the panel and with the unloaded side edges at the center lines of the rivet rows. For each width of flat sheet, the average strafn at the side edge was plotted against the average strain at the center.

The strain at the side edge was assumed to be the same as the strain in the corrugated sheet and was obtained from the strain gages attached to the corrugated sheet. (See fig. 3.) The strains at the middle of each width of flat alaeet were obtained by direct measurement. *(See* fig. 4.) The critical strain for the flat sheet was taken as that value of edge strain at which the curve of edge strain plotted against center strain showed a definite deviation from a straight line. The load on the panel at the critical strain was then obtained from a curve of load plotted against the average strain in the corrugated sheet, and this critical load was converted to the average stress on the cross section of the panel. For panel:: of the same cross section but of different lengths, the critical stresses were averaged and these averaged stresses are indicated in figures 5 and 6.

REFERENCES

1. Kotanchik, Joseph N., Weinberger, Robert A., Zender, George W., and Neff, John, Jr.: Compressive Strength of Flat Panels with Z- and Hat-Section Stiffeners. NACA ARR No. L4F01, 1944.

2. Anon.: Strength of Aircraft Elements. ANC-5, Army-Navy-Civil Committee on Aircraft Design Criteria. Revised ed., Dec. 1942.

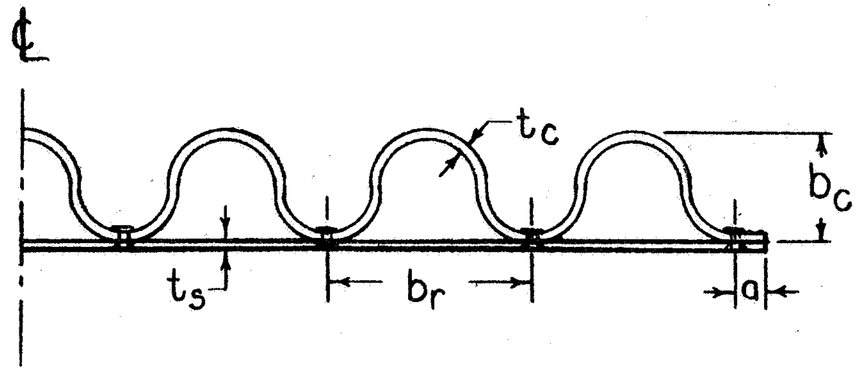

Figure 1.-Cross section of panel.
Seven corrugations, $b_c = 2$ in.

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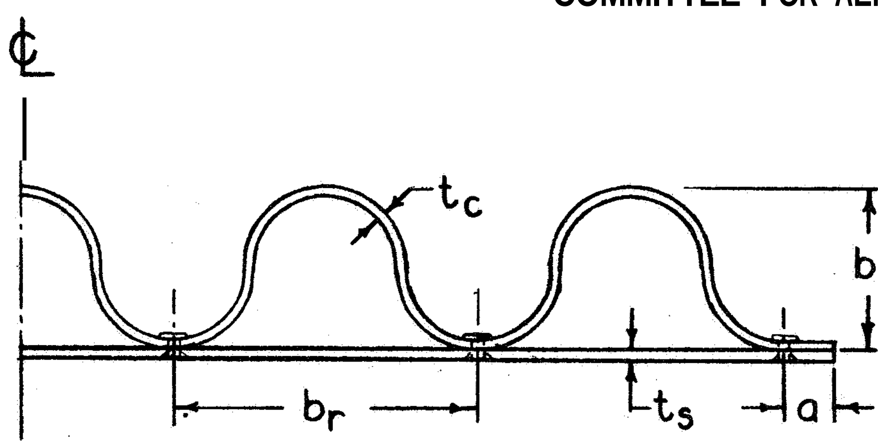

Figure 2.- Cross section of panel.
Five corrugations, b_c 3 in.

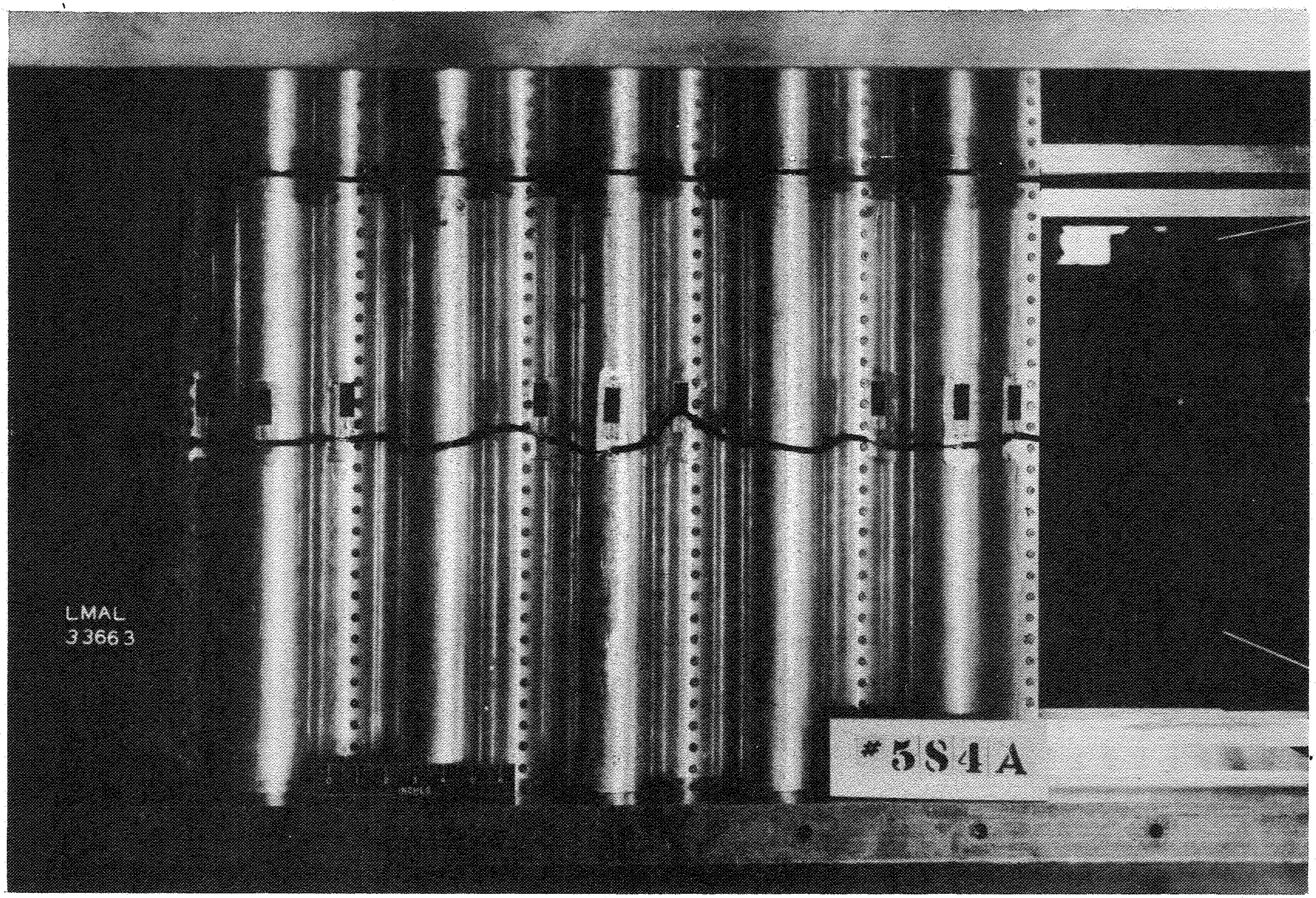

Figure 3.- A corrugated-sheet-stiffened specimen in testing machine ready for tests.

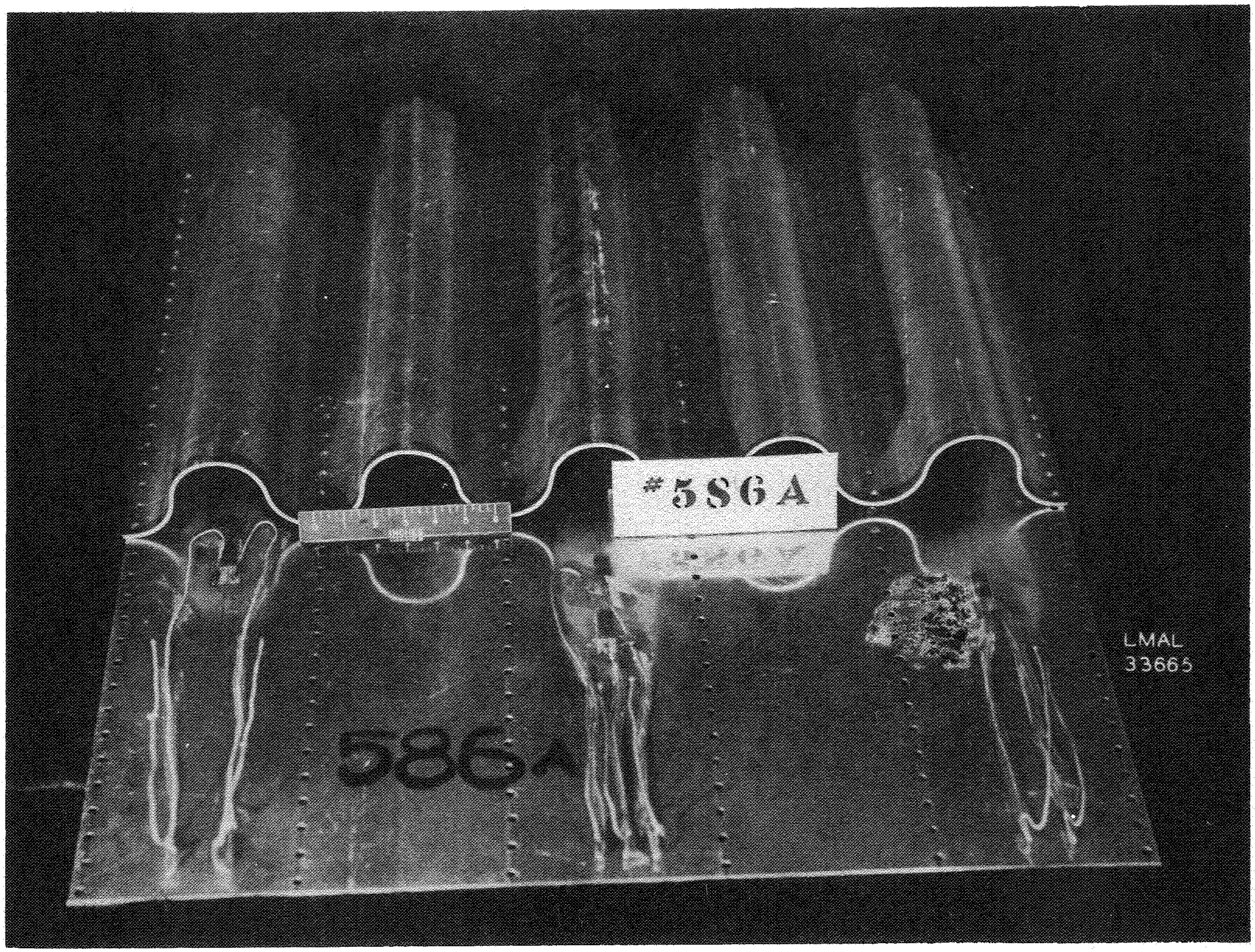

Figure 4.- Location of wire-resistance-type strain gages under the corrugated sheet.

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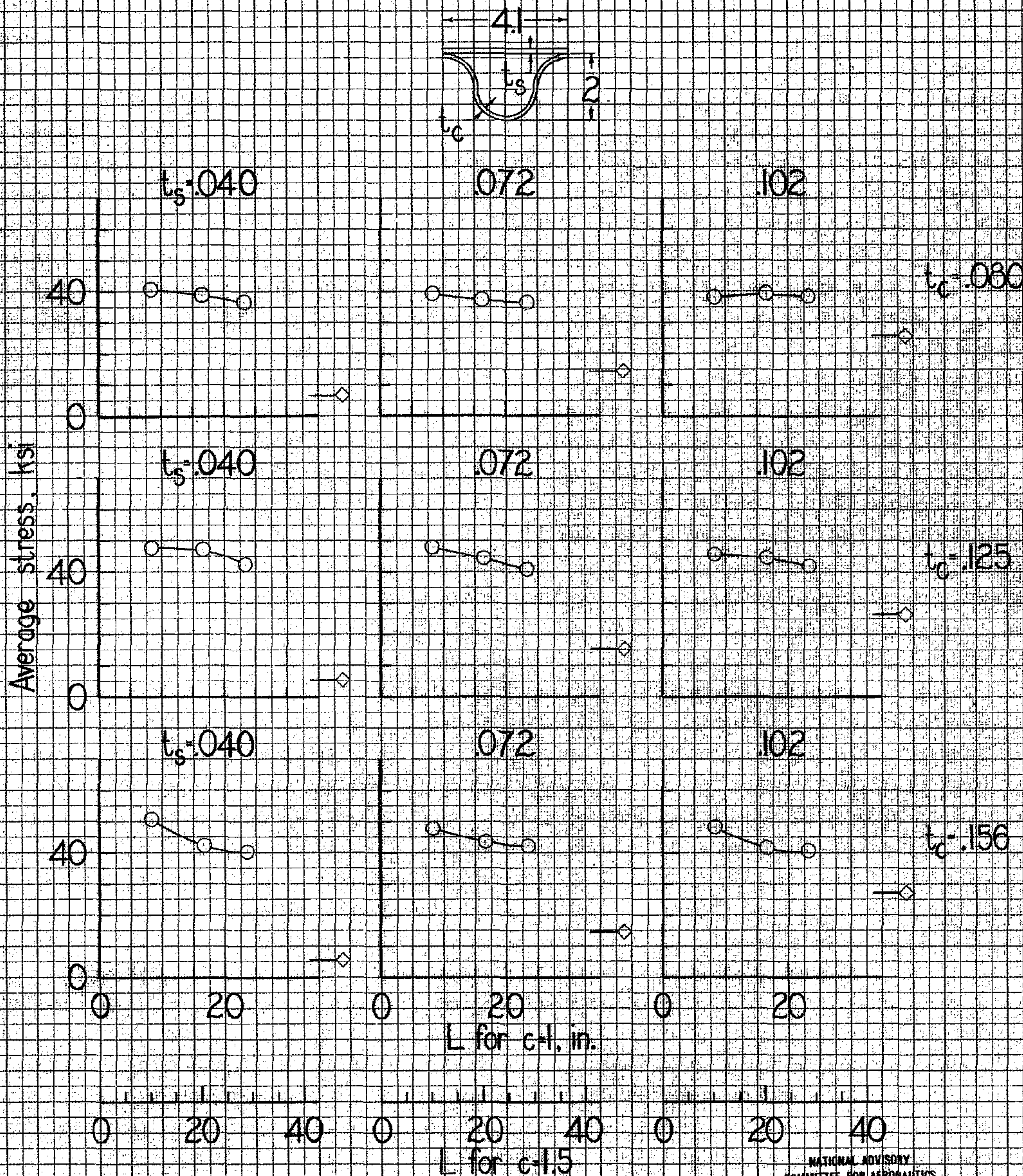
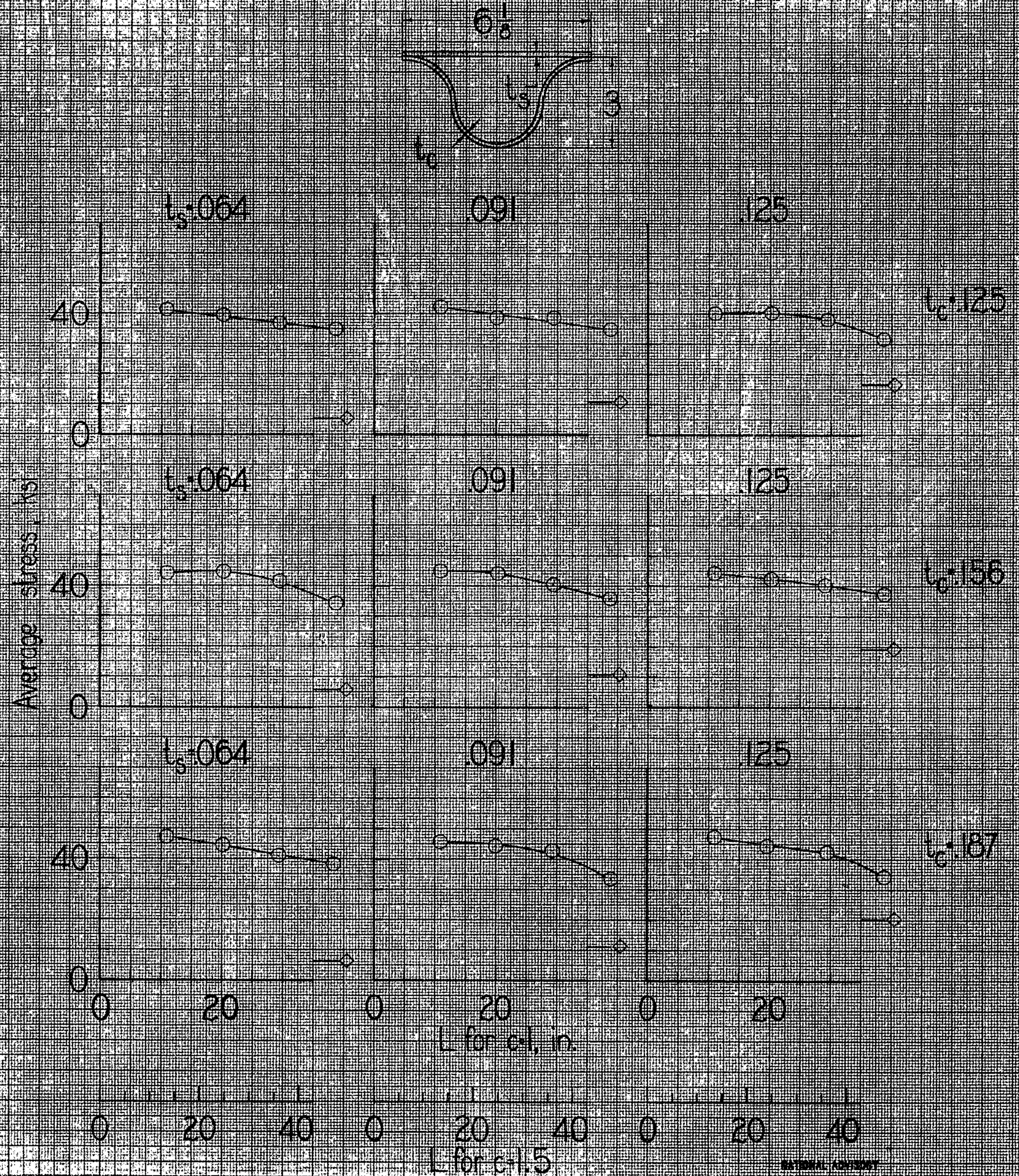


◇ Average stress when sheet buckling occurs.

Stresses adjusted to guaranteed yield strengths: Corrugation 48 ksi, sheet 57 ksi.

Figure 5.- Strength of panels stiffened with corrugated sheet. b_c=2 in. b_r=4.1 in.



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◇ Average stress when sheet buckling occurs.

Stresses adjusted to guaranteed yield strengths: Corrugation 46 ksi, sheet 57 ksi.

Figure 6.- Strength of panels stiffened with corrugated sheet. $b_C = 3$ in. $b_F = 6\frac{1}{8}$ in.